

Frequency Response of Post-down-converter Digital Filters in the MI BPM EchoTek Board Setup

Bob Webber
12 January, 2006

This note describes the required GrayChip setup file frequency parameters and the frequency response to be expected from the EchoTek/GrayChip post-down-converter digital filters used in the Main Injector BPM. The four channels in each GrayChip are configured as:

- 53 MHz narrowband (for closed orbit)
- 2.5 MHz narrowband (for closed orbit)
- 53 MHz wideband (for turn-by-turn)
- 2.5 MHz wideband (for turn-by-turn)

Configuration File Frequency Parameters

The Echotek configuration file requires specification of two frequency values for each GrayChip channel, the digitizer frequency and the down-convert frequency. Given a digitizer clock frequency 10/7 times the nominal 53 MHz signal, the proper relationships between digitizer and down-converter frequency values are $f_{\text{downconvert}2.5} = f_{\text{digitizer}}/30$ and $f_{\text{downconvert}53} = 3/10 f_{\text{digitizer}}$. Absolute value of $f_{\text{digitizer}}$ specified in setup file is not critical because the real frequency tracks the beam signal. The value used in the file is $10/7 * 53.10468$ [MI frequency at 120GeV] = 75.863829. This then requires the down-convert frequency value for the 53 MHz channel to be set to 22.759149 and that for the 2.5 MHz channel to be set to 2.528794.

Narrowband Filter Parameters

The narrowband channels are configured with a decimation of 1536 in the CIC and 2 in each of the CFIR and PFIR sections. With a digitizer frequency ~75.6 MHz (it tracks at 10/7 time MIRF), this gives a sampling interval of ~20.3 microseconds in the CFIR, ~40.6 μs in the PFIR and ~81.2 μs out of the PFIR.

The narrowband channel CFIR and PFIR filters each have eleven non-zero coefficients, shown in Table 1. These are the same for the 53 and the 2.5 MHz channels. The eleven tap “window” in the PFIR corresponds to a signal integration window of 447 μs (11 x 40.6 μs), that is about 40 MI turns.

Wideband Filter Parameters

The wideband channels have a CIC decimation of 8 and CFIR and PFIR decimations of 2 each. With a 75.6 MHz digitizer frequency, the sampling interval is ~106 nanoseconds in the CFIR, ~212 ns in the PFIR and ~424 ns out of the PFIR.

For the wideband channels, the CFIR has just two non-zero coefficients and the PFIR has four as shown in Table 2. The four tap “window” in the PFIR corresponds to a signal integration window of 848 ns (4 x 212 ns), about ½ of one Booster batch.

TOTAL_CFIR_COEFF= 11	TOTAL_PFIR_COEFF= 32
470	6000
1230	6000
2590	6000
4390	6000
6040	6000
8180	6000
6040	6000
4390	6000
2590	6000
1230	6000
470	6000

TABLE 1 Narrowband CFIR and PFIR Coefficients

TOTAL_CFIR_COEFF= 11	TOTAL_PFIR_COEFF= 32
32000	16000
32000	16000
	16000
	16000

TABLE 2 Wideband CFIR and PFIR Coefficients

Frequency Response

Since the sampling rates, CIC decimation, and CFIR and PFIR coefficients are identical for the 2.5 MHz and 53 MHz narrowband channels, only the down-convert frequency differs, the output frequency response of the two channels is the same. This is similarly true for the two wideband channels. The frequency responses and step responses for the narrowband and wideband channels are shown in Figures 1-6. The 3db bandwidth of the narrowband channels is 1 KHz and that of the wideband channels is about 500KHz.

Conclusion

Frequency response of the EchoTek digital filters for the Main Injector BPM configuration is shown. The narrowband (closed orbit) channels roll off to -3 dB at about 1 KHz. The response is not particularly flat up to 1 KHz and it is not clear that the filter attenuates betatron frequency signals as strongly as might be desired. There is some flexibility to allow the possibility of fine-tuning the narrowband filter parameters with these objectives in mind. The 3 db bandwidth of the wideband (turn-by-turn) channels is about 500 KHz. Operation at this bandwidth implies very few non-zero filter taps, leaving little flexibility for special tailoring of the frequency response.

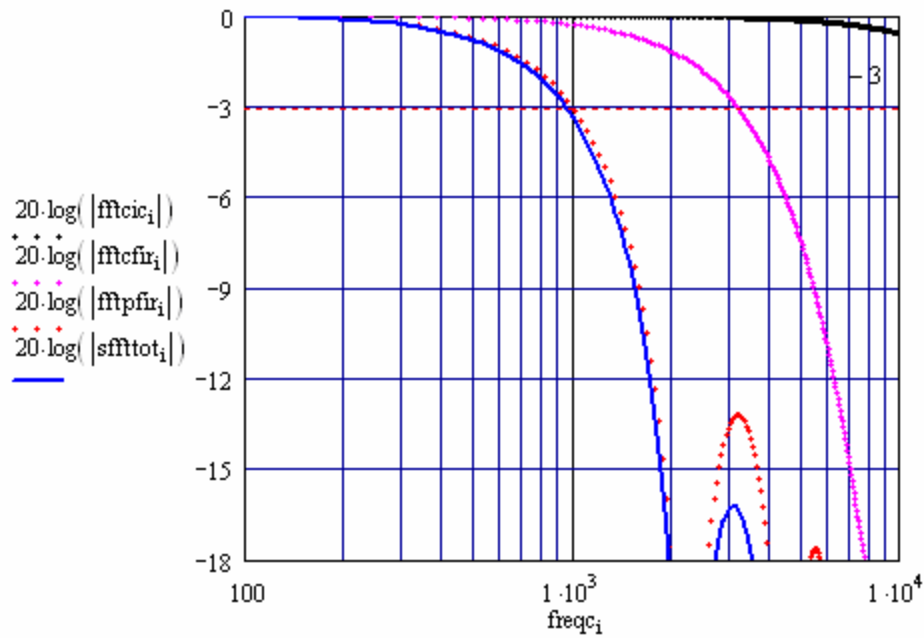


FIGURE 1 Narrowband Channels Filter Frequency Response (zoom)
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)
 Vertical scale dB, horizontal scale Hertz

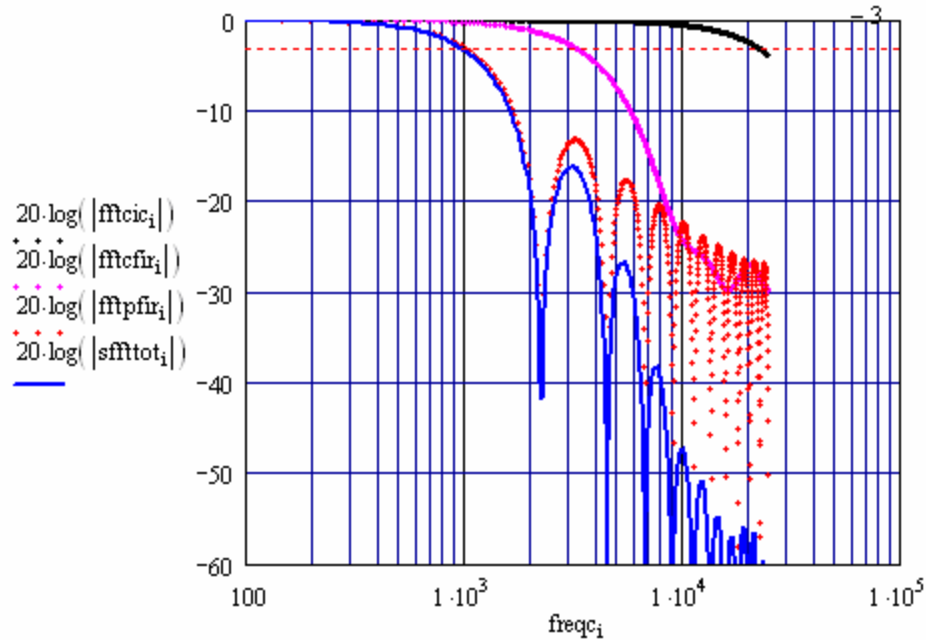


FIGURE 2 Narrowband Channels Filter Frequency Response (wide scale)
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)
 Vertical scale dB, horizontal scale Hertz

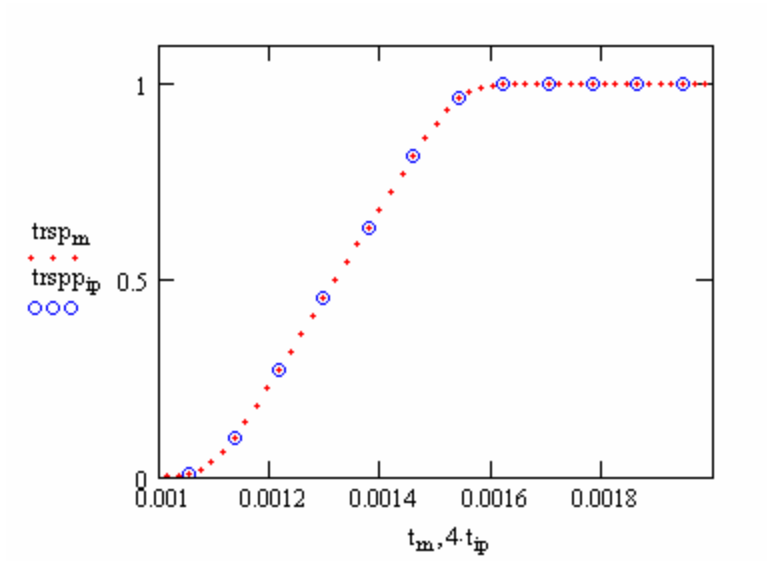


FIGURE 3 Narrowband Channels Combined Filter Step Response
CFIR data points (red dots) and PFIR output points (blue circles)
Vertical scale arbitrary, horizontal scale seconds

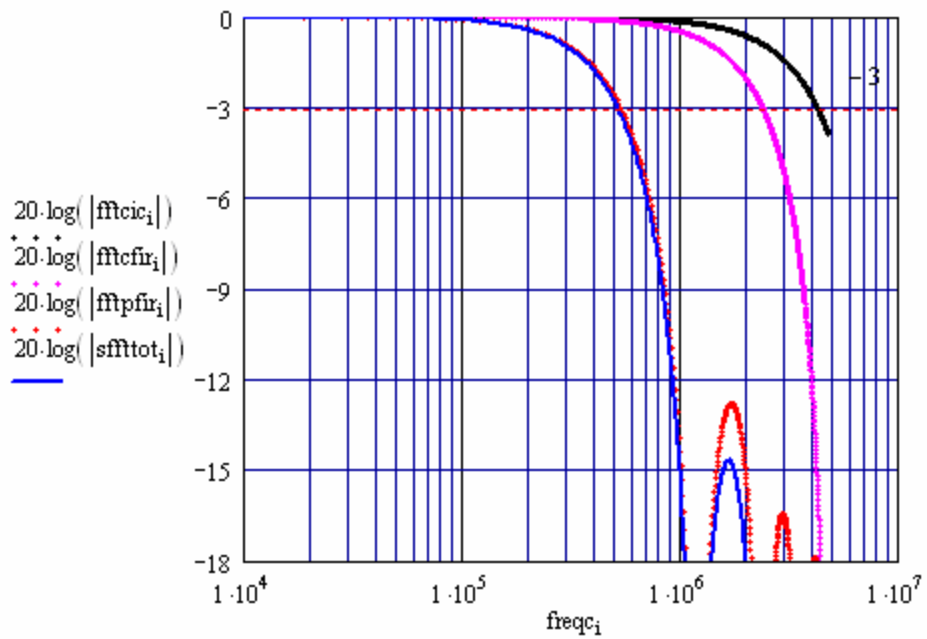


FIGURE 4 Wideband Channels Filter Frequency Response (zoom)
CIC (black), CFIR (magenta), PFIR (red), Combined (blue)
Vertical scale dB, horizontal scale Hertz

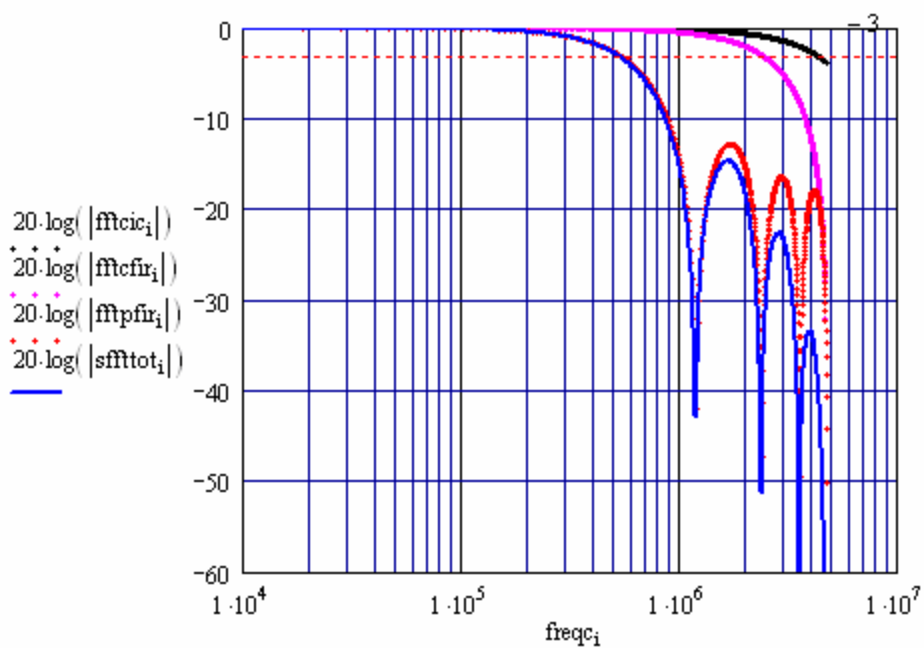


FIGURE 5 Wideband Channels Filter Frequency Response (wide scale)
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)
 Vertical scale dB, horizontal scale Hertz

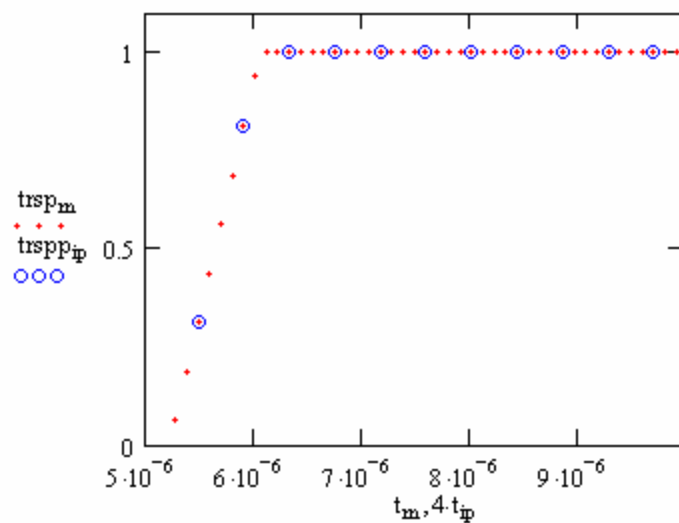


FIGURE 6 Wideband Channels Combined Filter Step Response
 CFIR data points (red dots) and PFIR output points (blue circles)
 Vertical scale arbitrary, horizontal scale seconds